REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
26-11-2001

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
Oct 98 - Oct 01

4. TITLE AND SUBTITLE
Pre-flight Physics-Based Infrared Synthetic Scene Simulation For Army Aviation Mission Enhancement

5a. CONTRACT NUMBER
NA

5b. GRANT NUMBER
NA

5c. PROGRAM ELEMENT NUMBER
PE62784

6. AUTHOR(S)
George G. Koenig, Robert E. Davis, and Major Steve Milton

5d. PROJECT NUMBER
4a762784AT42

5e. TASK NUMBER
AT42-3D001

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Engineer Research and
Development Center Cold Regions Research
and Engineering Center
72 Lyme Rd
Hanover, NH 03755

8. PERFORMING ORGANIZATION REPORT NUMBER

NA

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and
Development Center Cold Regions Research
and Engineering Center
72 Lyme Rd
Hanover, NH 03755

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

20020904 055

13. SUPPLEMENTARY NOTES

14. ABSTRACT Aviators rely heavily on Forward Looking Infrared (FLIR) imagery. Weather impacted terrain and targets significantly impedes an aircrew's ability to navigate and to rapidly and accurately detect and identify targets. Weather degradation increases target acquisition and identification times, subjecting the aircraft and crew to increased exposure to enemy threats and counterattacks, ultimately decreasing system lethality and survivability. The U.S. Army Engineer Research and Development Center (ERDC), the Air Force Research Agency (AFRA) and the U.S. Army Aviation Test Directorate, Operational Test Command tested the utility of the Infrared Target-scene Simulation Software (IRTSS) System as a mission planning and rehearsal tool for AH-64 Apache attack aviation. IRTSS translates information dominance into readily assimilated situational awareness by fusing tactical intelligence with weather intelligence. Increased situational awareness mitigates risk and improves aircrew/aircraft lethality and survivability. The IRTSS software running in a commercial web browser generated FLIR scenes for the AH-64 Target Acquisition Detection Site (TADS) providing a mechanism for systematically accounting for weather and weather-related effects on the terrain. This technology optimizes for both the anticipated tactical situation and environmental conditions. Using control and test groups of Army aviators, we tested the improvements IRTSS brings to ranking Battle Position (BP) in comparison to using hard copy maps and the Aviation Mission Planning System (AMPS). The tests also measured the change in target detection times using live TADS video following previews of IRTSS scenes.

15. SUBJECT TERMS
Synthetic infrared scenes/imagery, Physics-based thermal modeling, Mission preview, Intelligence preparation of the battlefield, Sensor simulation

16. SECURITY CLASSIFICATION OF: Unclassified

a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	UL	13	George G Koenig
					19b. TELEPHONE NUMBER *(include area code)* 603 646-4556

Pre-flight Physics-Based Infrared Synthetic Scene Simulation for Army Aviation Mission Enhancement

George Koenig, Robert E. Davis and MAJ Steve Milton
U.S. Army Engineer Research and Development Center
Cold Regions Research and Engineering Center
72 Lyme Road, Hanover, NH 03755
Voice: (603) 646-4556
Facsimilie: (603) 646-4278
George.g.koenig@erdc.usace.army.mil

69th MORS Symposium
Working Group 11
12-14 June 2001
(November 2001)

ABSTRACT

Aviators rely heavily on Forward Looking Infrared (FLIR) imagery. Weather and weather impacted terrain and targets can significantly impede an aircrew's ability to navigate and to rapidly and accurately detect and identify targets. Weather related degradation increases target acquisition and identification times, subjecting the aircraft and crew to increased exposure to enemy threats and counterattacks, ultimately decreasing system lethality and survivability.

The U.S. Army Engineer Research and Development Center (ERDC), the Air Force Research Agency (AFRA) and the U.S. Army Aviation Test Directorate, Operational Test Command tested the utility of the Infrared Target-scene Simulation Software (IRTSS) System as a mission planning and rehearsal tool for AH-64 Apache attack aviation. IRTSS translates information dominance into readily assimilated situational awareness by fusing tactical intelligence with weather intelligence. Increased situational awareness mitigates risk and improves aircrew/aircraft lethality and survivability. The IRTSS software currently runs as a Java applet in a commercial web browser. IRTSS generated FLIR scenes for the AH-64 Target Acquisition Detection Site (TADS) provides a mechanism for systematically accounting for weather and weather-related effects on the terrain. This affects mission planning and enhances aircrew situational awareness during mission execution. This technology optimizes for both the anticipated tactical situation and environmental conditions. Using control and test groups of Army aviators, we tested the improvements IRTSS brings to ranking Battle Position (BP) in comparison to using hard copy maps and the Aviation Mission Planning System (AMPS). The tests also measured the change in target detection times using live TADS video following previews of IRTSS scenes.

INTRODUCTION

Army attack and reconnaissance helicopters, such as the AH-64A/D Apache, OH-58D Kiowa Warrior and RAH-66 Comanche, use IR sensors as their primary target acquisition/confirmation sensor. The Apache, OH-58D (soon to be replaced by the Comanche) and Comanche platforms use Forward Looking Infrared (FLIR) sensors. Aviation warfighters rely heavily on FLIR imaging systems to navigate, to identify Battle Position/Firing Positions (BP/FP), to orient with the Engagement Area (EA) and to quickly and accurately acquire and identify targets.

Environmental conditions, such as weather-terrain interactions and terrain-target contrast relationships affect FLIR mission performance (Bryant, 1998). Some environmental effects on FLIR-warfighter performance can increase aircraft vulnerability by reducing the aircrew's ability to quickly and accurately identify visual cues when selecting battle positions/firing positions and orienting on an engagement area. Environment-related effects can also increase the time required for an aircrew to acquire targets.

Target-to-background contrast in terms of brightness temperature, Line Of Sight (LOS) conditions and viewing geometry, in terms of target-background pattern juxtaposition, control the appearance of targets at the aperture of a FLIR sensor. In a FLIR system, automatic and manual adjustments can enhance or reduce brightness and contrast, but cannot mitigate all environmental conditions, which affect the display and thus target detection and recognition. Target and background objects continually change temperatures as they heat and cool at different rates. The thermal state of the target, viewing aspect, target composition and terrestrial features combine to cause contrast radiance intensity relationships that can result in recognition difficulties for aviators using FLIR systems. These in turn, subject the aircraft and crew to increased exposure to enemy threats and counterattacks, ultimately decreasing system lethality and increasing crew and system vulnerability.

Thermal emission and reflection contribute to the apparent brightness temperature that IR sensors measure. On a hot day, the ground may reflect or emit more heat (electromagnetic energy in the IR spectral region) than the target. In this case, the environment will be "hot" and the target will be "cool". As the ground cools at night, the target may lose heat at a slower rate than the surrounding environment. Moreover, with an engine running, or exercised gun, a target vehicle may have brightness temperatures well above the background. When sufficient thermal contrast or brightness temperature difference exists (generally ± 1-2 C°) between a target and the surrounding background within the sensor view, a human should detect the target. The delta temperature between the target and the background required for target detection is difficult to predict because of the complex environmental impact on both the target and the background temperatures. (Schlessinger, 1995). At some point during a day-night cycle the emission of heat from both the target and the surrounding environment may match, referred to as "IR crossover". At the IR crossover both the target and the background may have nearly identical brightness temperatures, which make target detection and recognition difficult to impossible. Figures 1 and 2 show examples of predicted FLIR scenes with vehicle targets to illustrate these concepts. Generally, the less contrast in background terrestrial features and between the features and targets, the longer it takes a human to make confirmed recognition (Bryant, 1998).

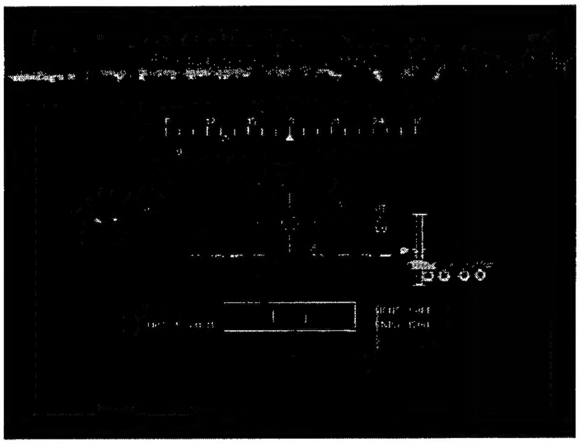

Figure 1. FLIR scene predicted for Test Range at Camp Grayling MI. In this scene the T-72 (left center) and the BTR 70 (right center) stand out with moderate to high contrast.

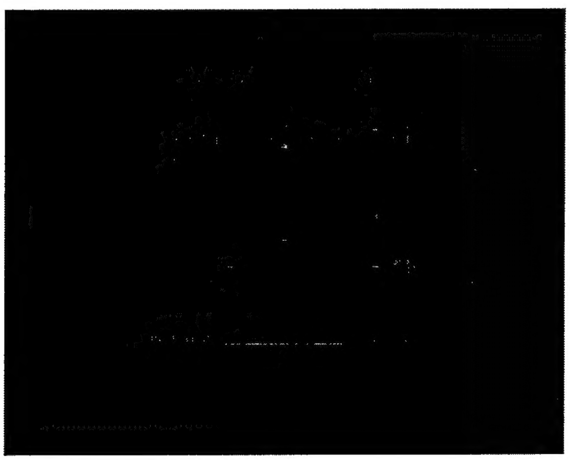

Figure 2. FLIR scene predicted for Test Range at Camp Grayling MI. This example, near the daily cross-over of background temperatures under cloudy skies, shows how time and weather can make target detection difficult.

Aviators can experience difficulties in selecting a BP and detecting and identifying targets in an EA when landmarks are not recognized, or difficult to locate. This problem can be compounded if the aviator chooses the landmarks exclusively from pre-mission visual products and uses the FLIR during the mission execution. A one-to-one mapping between a visual and corresponding infrared image does not exist.

Synthetic infrared (IR) imagery has the potential to significantly improve mission planning by allowing the aviators to view image products that visualize the appearance of the EA from different BP/FP (or navigation way points) prior to the mission. Specifically, predicted FLIR scenes could improve Intelligence Preparation of the Battlefield (IPB), mission rehearsal and target acquisition for warfighters using IR sensing systems to navigate and/or acquire targets. This research focuses on the quantitative evaluation, in terms of military utility and value added, of synthetic IR image products provided to the aviation warfighter prior to, or during, missions.

Current technology supports the capability to render high fidelity, physics-based, predictive IR scenes. By accounting for sensor response and viewing characteristics, one can tailor synthetic scene generation to the individual aircraft (system) sensor platform (e.g., Apache FLIR). Different government and commercial software systems can render synthetic IR scenes, and a few incorporate thermal models of terrain and targets to adjust scenes based on weather and terrain response. For example, the Infrared Target-scene Simulation Software (IRTSS) provides aviators and mission planners with predicted, physics-based IR scenes for use in mission planning and rehearsal.

This software gives the users a "through the sensor" synthetic infrared image based on expected weather at mission time. The experiment reported in this paper will measure, in a classroom setting, the change in Battle Position ranking, target detection time and the number of target false and non detections of a group of aviators who previewed various IRTSS image products compared with a group of aviators who used current planning tools.

INFRARED SCENE PREDICTION

Modeling systems that generate synthetic IR scenes require predicted terrain and target radiant temperatures based on the physical, optical, and thermal properties of the terrain and target. They also need methods to account for atmospheric transmission of the radiant energy between the terrain/target and the IR sensor, and a rendering scheme. Further, if the system predicts atmosphere-surface interaction, it requires both a set of thermal models for energy and mass transfer processes and a suitable computing architecture. Figure 3 provides a notional flow of information from terrain and weather, through thermal models driven by weather, to the user requirements and final rendering of the image products. In this experiment, we use a modified version of the Infrared Target-scene Simulation Software (IRTSS), developed by the Radex Corporation jointly with Air Force Research Lab (AFRL), Hanscom AFB, MA (Seeley and Luker, 1998). IRTSS evolved from the system of thermal models, radiance calculations, atmospheric transmission predictions and rendering codes originated by the Smart Weapons Operability Enhancement (SWOE) program (Welsh, 1994; Koenig et al. 1995; Welsh and Link, 1995).

Using terrain data layers, a process of categorical combination produces a model domain map where each element, or polygon, on the map represents an area with relatively uniform material thermal properties. The model domain map has an associated table that controls running the thermal models (Kress, 1992; Ballard, 1994). IRTSS uses separate models for forest areas, vegetation over ground and bare ground. For forested areas, the models follow the scheme originated by Verhoef and Bunnik (1975).

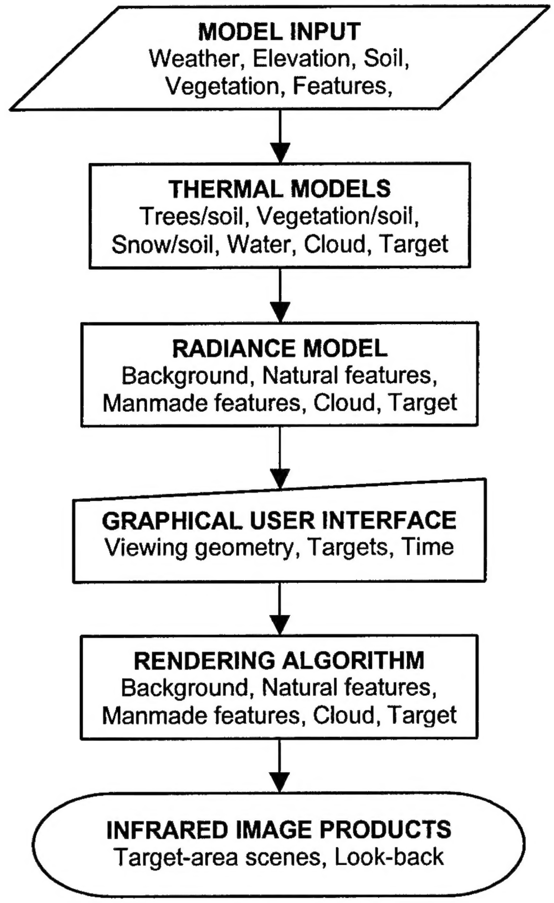

Figure 3. Notional flow chart of the process to predict IR scenes. Model input, thermal and radiance models assembled prior to use, with the exception of weather data. Input to the graphical user interface defines period of weather data use and scene specifications.

Smith et al. (1981) extended this to estimate a full expression of the energy and mass balance of a canopy-soil system, which assumes plane-parallel uniform properties of the tree canopy. The coupled vegetation-soil modeling approach follows Balick et al. (1981) with Deardorff's (1978) approach to calculate the soil moisture and Buck's (1981) equations for computing the vapor pressure in the system. Jordan (1991) developed the model used for soil and snow, which simulates most of the important physical processes in snow, but assumes that conduction dominates heat transfer in the

soil system. This model uses the materials properties in the modeling systems described by Guryanov (1985).

Synthetic IR scenes from the SWOE modeling suite have seen significant scientific validation using measured infrared scenes (Welsh, 1994). Statistical techniques (Siegel and Castellan, 1988) included comparison of measured and synthetic image histograms, comparison of relative temperature differences between scene features, and spatial variation of temperatures from pixel to pixel in both the synthetic and measured imagery. These analyses showed absolute accuracy on the order of few Kelvin and relative accuracy (contrast) on the order of one Kelvin.

INFRARED TARGET-SCENE SIMULATION SOFTWARE

The IRTSS provides the capability to generate "through-the-sensor" target scene predictions in the thermal IR waveband that include the effects of weather and time of day on a specific weapons system. This capability can also be extended to the night vision goggle, and visible wavebands. Recently tailored for Army Aviation applications (low and slow), IRTSS generates synthetic Forward Looking Infrared (FLIR) scenes and animations for the Target Acquisition Detection Site (TADS) of the AH-64 Apache. In rendering FLIR scenes, the IRTSS adds individual trees and buildings in addition to targets to generate line sight (LOS) that includes the effects of these features. The developers of the IRTSS intended to provide the aviation warfighter with pre-flight awareness of the impacts of weather and terrain on his FLIR system.

The IRTSS runs under client-server architecture and combines physics-based thermal and IR signature models with weather data to produce FLIR scenes and simulate cockpit video. High-resolution thermal models of atmosphere-terrain interaction in the IRTSS server make predictions of the surface temperature everywhere in an area of interest at selected times. The surface temperatures in turn provide input to rendering software that generates IR scenes for any viewing geometry, which can form time series and thus animations for delivery to the client.

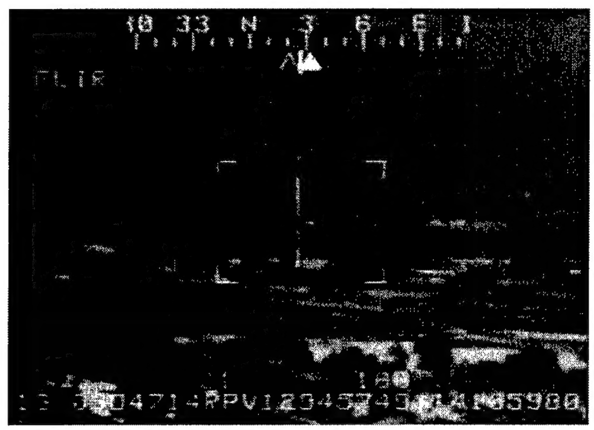

Figure 4. Comparison of IRTSS Scene (top) and actual AH-64 TADS FLIR scene (bottom). Both have medium field of view, white-hot polarity.

IRTSS has incorporated a sensor model, representing a NATO system, with viewing geometry and sensor characteristics similar to the Apache TADS so that the scenes used in this test represent a credible surrogate to what an Apache Co-Pilot / Gunner sees on a TADS display. Figure 4

shows a comparison of an IRTSS scene an Apache TADS scene digitized from actual video footage to the same viewing geometry and time of day at Fort Hood, TX. Inputs to IRTSS include weather, target type and location, sensor type and characteristics, land feature and terrain elevation data. Typical IRTSS products show the view from the TADS to the target area. Additional products include "look-back" images showing a FLIR view toward the direction of the unmasked Apache from the target location.

On the client, a user interacts with a Graphical User Interface (GUI) and a specified terrain database to select a time or time period of interest, a target location or look-at point, a viewer location or viewing route, a target type or types of targets, a sensor type and the type of image product desired. Under operational conditions, the aviation mission planner would perform these actions using the GUI executing through a browser on the client side.

Generating an IRTSS visualization first requires specifying a scenario: a geographic location populated with a set of targets. It also allows the user to save scenarios and re-load or edit them in future sessions. After scenario specification, the user has the option of executing the IRTSS models, using automated weather data, or with more accurate local information. The models also require a valid time for the scenes, which must correspond to times weather information is available for model initialization. Use of weather information from a mesoscale forecast model will provide a prognostic capability allowing the user to generate a series of scenes over the time period of the forecast weather conditions. Model execution takes several minutes, after which the user can generate IR scenes at different ranges, altitudes, headings, and mission times, without re-running the thermal models.

An IRTSS installation comes packaged with geographic and target data sets. Terrain analysts generate the geographic data sets in a semi-automated fashion from standard terrain data (e.g., NIMA coverage) or multi-spectral imagery, from commercial or national sources, and from elevation data. Target data represent target geometry and material composition at various scales. IRTSS presently has approximately 50 different target objects. These objects range from buildings and bunkers to surface-to-air missile (SAM) sites and individual tracked and wheeled vehicles, both US and foreign.

HYPOTHESES

This concept experiment has the context of the tactical operating domain of the AH-64A helicopter employing the Hellfire missile, the primary weapons system for high priority targets. The Apache helicopter has two model variants: the AH-64A Apache and the AH-64D Apache Longbow. Both currently have identical IR sensors and operate in the 8-12 μm wavelength band. The Target Acquisition Designation Site (TADS) is the primary IR sensor used for target detection prior to release of ordnance. This experiment focuses on the military worth and utility of predictive FLIR technology for the TADS, used by the Co-Pilot Gunner during actions in an Engagement Area.

The IRTSS, modified for Army aviator use, has the potential to significantly improve mission planning and rehearsal. The experiment design aims at quantitative measurement of the military value of synthetic IR scenes viewed prior to attack mission operations. The hypotheses address critical tasks:

Hypothesis 1: *Battle Position Evaluation* - Synthetic TADS scenes, used as previews to missions, assist Apache mission planners in

evaluating and ranking Battle Positions (BPs) and Attack-by-fire Positions (ABFs).

Hypothesis 2: *Situational Awareness and Risk Mitigation* - The IRTSS capability to generate "look-back" scenes, from the target to the Apache, provides increased situational awareness useful for risk mitigation.

Hypothesis 3: *Target Detection and Identification* - A. Synthetic TADS scenes decrease Co-Pilot/Gunner (CPG) target detection times. B. Further, this decreases target identification times. C. Preview scenes improve CPG target detection accuracy (decrease number of false detects) and/or target acquisition (decrease number of non-detects).

Hypothesis 4: *Enhancement to the Aviation Mission Planning System (AMPS)* - Access to pre-mission, synthetic TADS scenes (e.g., through AMPS) and FLIR scenes in general improve the IPB process, Battalion – Platoon planning / unit rehearsals and aircrew/aircraft risk mitigation.

EXPERIMENTAL METHODS

The Army's Aviation Test Directorate (AVTD), Operational Test Command will administer the test evaluating products from IRTSS to determine the value added of synthetic TADS scenes and animations for Apache attack mission planning and rehearsal. They will conduct the test at Fort Hood, Texas using 30 AH-64 pilots from 1-4 Avn BN (Attack), 4th Infantry Division.

The experiment will measure and record the measure of performance (MOP) of 30 AH-64A Apache helicopter pilots in two primary areas: battle position selection and target detection. AVTD will divide the pilots, cross-leveling by experience (flight hours, years of service, flight rating, rank, current command position, etc.) into two groups: a baseline group and an IRTSS group. The experiment will consider the baseline group as the "status quo" group. The baseline group will receive the standard set of mission planning information that Apache pilots receive during actual training and combat missions today. The IRTSS group will serve as the experiment's enhanced group. The IRTSS group will receive the same set of mission planning information as the baseline group. Additionally, the IRTSS group will receive predicted FLIR scenes as part of their mission planning materials. Both groups will have the same amount of time to review their respective planning information prior to the tests. The IRTSS group will not receive additional training on how to use the IRTSS scenes. Rather, they will have the simple statement that "The IRTSS scenes represent a close match to what they would see in actual TADS FLIR for each specified time, location and engagement."

In the tests, a series of vignettes comprised of TADS video, pre-recorded at notional BPs will represent "actual" missions. The recordings show the view from an Apache TADS: 1) as the aircraft unmasks to view an area potentially containing targets, and 2) scans a target area (notional EA) that contains target(s). The test will measure the changes to battle position evaluation and target detection when a group of pilot test subjects has had the opportunity to use IRTSS products in addition to a set of standard mission planning tools. This test will not evaluate the IRTSS client-server architecture, GUI, scientific validity of the synthetic TADS scenes, or the differences between using forecasted weather conditions verses measured weather.

The tests will use a classroom setting. AVTD test officers will administer the test. An AVTD test team of three test officers (two individuals to administer the test and one person to in-process and out-process test

subjects) will execute the tests. AVTD Operations Research Systems Analyst (ORSA) will conduct the analysis of test results. Pilots in each group will take the test individually using a personal computer to view the video materials, the TADS and IRTSS scenes, one-on-one with an AVTD test administrator. Individual test subjects will remain in their assigned group throughout all testing. Pilots will have instructions to assume they will perform the duties of the CPG for all missions with a mission Fragmentary Order (FRAGO), the same for both groups. Upon completion of the FRAGO they will have access to their groups' respective mission planning tools. Each group of 2 pilots will have the same amount of time to review their mission-planning tools. AVTD test administrators will then instruct pilots to watch a series of pre-recorded and digitized TADS FLIR videos (simulating the views of an AH-64 CPG). The pre-recorded TADS FLIR videos serve to measure the test subjects' decisions in two phases of the test – hypotheses 1 and 3: BP ranking and target detection. A third phase of the test will consist of a written survey in which test subject responds to the IRTSS image products, addressing hypotheses 2 and 4.

Thirty U.S. Army AH-64A Apache helicopter pilots from 1st Battalion, 4th Aviation Regiment, 4th Infantry Division, Fort Hood, Texas will perform as subjects for this experiment: fifteen subjects in the Baseline group and fifteen different subjects in the IRTSS group. All test subjects are commissioned officers in the rank of Warrant Officer 1 to Captain. All test subjects have a minimum of 195 AH-64A flight hours and most had over 600 hours.

Battle Position Selection

This part of the testing program will quantitatively measure the performance improvement of pilots' ability to optimally rank order battle positions, given baseline materials and given IRTSS mission planning and rehearsal tools. In order to establish a standard of reference, an aviation Standardization Instructor Pilot (SIP) with access to all materials, including live pre-recorded TADS videos and IRTSS products established the rank order for each BP in each EA.

For mission planning individual pilots in both groups will read a copy of the mission brief (FRAGO). They will review a Fort Hood 1:50,000 topographic map with BPs and EAs and color screen prints of line-of-sight (LOS) plots on a 1:50,000 scale map from the Aviation Mission Planning System (AMPS). AMPS LOS prints will include LOS plots from each BP to its respective EA, in increments of 50 feet (50-200 ft) above ground level (AGL). Additionally, pilots will have a copy of the tasks, conditions, and standards and other reference materials. Test subjects can ask questions to clarify tasks-conditions-standards. Test subjects will have 20 minutes to review mission planning materials for each EA (40 minutes total mission preparation time to complete both EAs). Upon the completion of each 20-minute review, each test subject in each group will evaluate and rank order (from best to worst) two sets of five (10 total) pre-selected BPs arranged around notional engagement areas (EAs).

For each EA, the Baseline test subjects will evaluate an initial rank order to the first group of five BPs after reviewing standard planning tools. Test subjects will then view pre-recorded TADs video in medium and narrow fields of view (MFOV/NFOV), showing the views of the target area as an Apache unmasks from each position, and given the opportunity to change their ranking. Each video averages 60 seconds in duration. Each engagement area had three VISMOD HMMWV as targets. As the Apache reaches an altitude that achieves line

of sight with the target, the target remains in the field of view continuously. Not all BPs achieved LOS within the imposed 300-foot altitude. The subjects will then reevaluate their rank order based on new information in the recorded live videos.

The metrics for this part of the test series will result from comparing different rank order evaluations of BPs after different stages of the test for each group. Comparison of the Baseline group initial rank order of BPs with the reference (SIP) BP rankings, and the Baseline group rankings before and after review of pre-recorded video form the metrics for this group. Similarly, comparison of the IRTSS group initial evaluations of rank order of BPs with the reference (SIP) rank order, and again with the evaluations after review of pre-recorded video form the metrics for the IRTSS group.

In addition to the standard planning tools, the IRTSS group will view IRTSS static scenes, including "look backs" from the target to the Apache position, and synthetic animations of unmasking and scanning within the EA, with TADS-like symbology, before establishing an initial rank order of the two sets of five BPs. Test subjects from this group will then view the same pre-recorded live TADs video and reevaluated a final rank order to the BPs. The groups will respond to survey questions about the merit, or value, of the synthetic scene products, addressing issues associated with hypotheses 2 and 4.

Target Detection

This part of the test series will quantitatively measure the performance improvement of pilots ability to accurately detect enemy targets in a given engagement scenario, given pre-mission IRTSS mission planning and rehearsal tools. The test station will remain the same from the previous part of the experiment. As, before, individual pilots (in both groups) will read the same mission brief (FRAGO), and review a Fort Hood 1:50,000 topographic map with BPs and EAs. This part will not use AMPS line-of-sight screen prints. Other materials and conditions will remain the same as the previous test sequence. Each test subject will have 5 minutes to review his or her respective mission planning information.

Following the planning period the test subjects will view a pre-recorded live TADS video, (MFOV, white-hot polarity) and attempt to detect enemy targets, therein portrayed by HMMWV VisMods. The two groups of test subjects will view the same eight pre-recorded videos, in the same order. The IRTSS groups will view IRTSS scenes prior to viewing pre-recorded TADS video. Each test subject will verbally state, "detect" and point to the candidate target spot on the display, at which point the AVTD test administrator will stop the video and note the elapsed time. Test administrators will have visual answer keys, which provide them detailed knowledge about which bright spots in the live videos represent the HMMMV VisMod target and which represent competing IR sources, not targets. The test administrator will record times to each detection and accuracy (correctly detected: yes/no). If false detection occurs, the administrator will pause the timer (video playback) and state to the subject "We have ascertained using your notional Narrow Field of View (NFOV) on your TADS that you just detected a false target; proceed with the test." The AVTD test administrator will then start the video from the paused position. With the remaining time until video's end, the test subjects continue to attempt to detect targets. This process will continue until either the test subject have correctly detected the enemy targets or the video ended, at which point the administrator would record the total time and indicate a non-detect.

The test administrator will repeat the above procedures for 8 target detection scenarios, allowing 5 minutes for "mission planning" and material review prior to each timed TADS video. Each video averages 60 seconds in duration. Each engagement area has one VISMOD HMMWV as a target. As the Apache reaches an altitude that achieves line of sight with the target, the target remains in the field of view continuously. The pilots run through each engagement in a random order. Targets appeared in alternating/random corners of the screen.

The raw data from this part of tests includes the total elapsed time and the number of false/non detections for each test subject for each video. The percent of correct identification for each group will also form a measure.

Pilot Survey

The pilot surveys have a focus on hypotheses 2 and 4. Upon completion of the BP selection and target detection tests, all 30 pilots will respond to a written questionnaire which contains 22-26 yes/no questions relating to parts one and two of the experiment. Pilots will have 10 minutes to complete the survey and add comments if desired.

Analysis

The Army Test and Evaluation Command (ATEC) will perform the formal analysis of the data. They will use a series of statistical and category procedures to directly address hypotheses 1-4 set forth in the experiment test plan. Additional statistical tests will provide a measure of confidence in the results of the statistical analysis addressing the impact of pre-mission IRTSS synthetic scenes on BP selection, decrease target detection time, and number of false and non-target detections.

DISCUSSION

IRTSS predicted synthetic scenes provide the warfighter a "through-the-sensor" view, an operational capability not available today as a pre-mission Army aviation planning tool. Visual imagery does not map one-to-one with FLIR imagery and offers limited mission enhancement. Only physics-based models can accurately depict complex terrain features and the non-linear terrain-atmosphere interaction. A capability like the IRTSS provides the warfighter two main operational benefits. First, it allows the mission planning process to directly and quantitatively account for weather to determine a mission profile (time over target, ingress/egress, weapons selection, etc.) that is optimized for both the anticipated tactical situation and environmental conditions over the target. Mission planners can view predictions of how a target will appear (position relative to broad geographic features and contrast against immediate background) for a variety of mission profiles. The second operational benefit comes from enhanced aircrew situational awareness during mission execution. Before flying a mission, aircrews can view a "through-the-sensor" physically accurate representation of target position and contrast relative to broad geographic features in the sensor waveband. This facilitates long-range target detection and positive target identification (Bryant, 1998). The net result reduces the amount of effort and time needed for a system operator to carry out a mission.

IRTSS translates information dominance into readily assimilated situational awareness by fusing tactical intelligence with weather intelligence. IRTTS synthetic scenes depict weather effects in a form that a non-meteorologist can easily understand and apply. Additionally, IRTSS has the capability to render both spatial and temporal animations.

For mission planning, IRTSS predictive scenes convey information on minimum altitude required for observation and weapons deployment (Fields of Fire), route planning, target planning, and battle position evaluation and selection. Additionally, IRTSS scenes provide the planner with information on whether targets will be visible at user-specified ranges (i.e. from weapon maximum effective range down to minimum acceptable "close" range) and the polarity of terrestrial and man-made features likely to be interpreted as false targets / hot spots. Using IRTSS, mission planners can easily and quickly change mission time, location, targets, sensor parameters (either sensor type or specified field of view) during the IPB process and during coarse of action development.

For mission rehearsal, IRTSS predicted scenes allow the warfighter at the company down to the individual aircrew level, to conduct a "visual, through-the-sensor practice" of their respective engagements. IRTSS scenes facilitate FLIR rehearsals starting from aircraft takeoff, ingress along the route, to the objective, and egress back to safety. Warfighters significantly mitigate risk, as IRTSS increases situational awareness and aids in pre-mission crew coordination.

Originally developed for the Air Force F-16 program, IRTSS scenes have also been verified, validated, and accredited for use and application for Navy F/A-18 fighter aircraft. IRTSS scenes are currently being used at Eglin Air Force Base and Fallon Naval Air Base. IRTSS applications are used primarily as a mission planning and rehearsal tool to enhance onboard FLIR sensors and improve target recognition and target detection times. Both the Air Force and the Navy have conducted limited experiments, which proved IRTSS scenes improve target detection and aviator confidence.

ACKNOWLEDGEMENTS

The Air Maneuver Battlelab, Fort Rucker, Alabama funded this project under the U.S Army Concept Experimentation Program (CEP). Co-sponsors and experiment participants include the Engineer Research and Development Center (ERDC), Virtual Target Center, Huntsville, AL, the Aviation Test Directorate, U.S. Army Operational Test Command, TEAC USA, and the Air Force Research Laboratory (AFRL).

REFERENCE LIST

Balick. L. R., R. K. Scoggins, and L. E. Link 1981, Inclusion of a Simple Vegetation Layer in Terrain Temperature Models for Thermal IR Signature Prediction, *IEEE Transactions on Geoscience and remote Sensing*, GE-19(3):143-152.

Ballard, J. R. 1994 Grayling I Information Base Procedures for Generation of Synthetic Thermal Scenes: Final Report, SWOE Report 94-1, US Army Cold Regions Research Engineering Laboratory, Hanover, NH.

Berk, A., Bernstein, L.S., and Robertson, D.C. 1989 MODTRAN: A Moderate Resolution Model for LOWTRAN 7, U.S. Air Force Phillips Laboratory, Geophysics Directorate, Hanscom AFB, MA 01731, Rept. No. GL-TR-89-0122.

Bryant, E. V., 1998, A Process Simulation Design to Assess Promising Technologies Relevant to F/A-18 Aircrew Target Recognition, Thesis: Masters of Science in Information Technology Management, September 1998, Advisor: William K. Krebs, Department of Operational Research, Associate Advisor: Terrance C. Brady, Department of Systems Management, Naval

Postgraduate School, Monterey, CA 93943-5000.

Buck, A. 1981 New equations for computing vapor pressure and the enhancement factor, *Journal of Applied Meteorology,* 20(12):1527-1532.

Deardorff, J.W. 1978 Efficient prediction of ground surface and moisture with inclusion of a layer of vegetation, *Journal of Geophysical Research,* 1889-1902.

Guryanov, I.E. 1985 Thermal-physical characeteristics of frozen, thawing and unfrozen grounds *Fourth International Symposium on Ground Freezing,* Sapporo, Japan, 225-230.

Idso, S. B. 1981 A set of equations for full spectrum and 8-14 μm and 10.5-12.5 μm thermal radiation from cloudless skies, *Water Resources Research,* 17: 295-304.

Jordan, R. 1991 A one-dimensional temperature model for a snow cover: Technical Documentation for SNTHERM.89, USA Cold Regions Research and Engineering Laboratory, Special Report 91-16.

Koenig, G.G., Welsh, J.P., Wilson, J., Smart weapons operability enhancement synthetic scene generation process, SPIE—The International Society for Optical Engineering. Proceedings, 1995, Vol.2469, Targets and backgrounds: characterization and representation, Orlando, FL, Apr. 17-19, 1995. Edited by W.R. Watkins and D. Clement, p.254-265

Kress, R. M. 1992 Information Base Procedures for Generation of Synthetic Thermal Scenes: Final Report, SWOE Report 92-1, US Army Cold Regions Research Engineering Laboratory, Hanover, NH.

Schlessinger, M. 1995 Infrared Technology Fundamentals. (2nd ed.) New York: Marcel Dekker, Inc.

Seeley, G. and S. Luker, 1998, Infrared Target Scene Simulation Software, *Battlefield Atmospherics and Cloud Impacts on Military Operations [BACIMO] Conference*, AFRL Hanscom AFB, MA 12/1-12/3 1998, p. 340.

Siegel. S. and Castellan, N. J. Jr. 1988 *Nonparametric Statistics for the Behavioral Science (second edition)* New York: McGraw-Hill.

Shapiro R. 1972 Simple model for the calculation of the flux of solar radiation through the atmosphere, *Applied Optics*, 11, 760-764.

Shapiro R. 1982 Solar radiative flux calculations from standard surface meteorological observations, U.S. Air Force Geophysics Laboraory, Hanscom AFB, MA 01731, Rept. No. AFGL-TR-82-0039.

Smith, J.A., K.J. Ranson, D. Nguyen, L.K. Balick, L.E. Link, L. Fritchen, and B.A. Hutchison 1981 Thermal vegetation canopy model studies, *Remote Sensing of Environment,* 11:311-326.

Verhoef, W., and N.J.J. Bunnik 1975 A Model Study on the Relations Between Crop Characteristics and Canopy Spectral Reflectance, NIWARS publications No 33, 3 Kanaalweg Delft, The Netherlands, 89p.

Welsh, J.P. 1994 Smart Weapons Operability Enhancement (SWOE) Joint Test and Evaluation (JT&E) Program. Final Report, U.S. Army Cold Regions Research

and Engineering Laboratory. SWOE report, Aug. 1994, No.94-10, Var. p., ADB-194 042.

Welsh, J.P., Link, L.E., Jr. 1995 Synthetic scene generation process for smart weapons, Army RD&A, July-Aug. 1995, p.33-36.

DESCRIPTORS

Synthetic infrared scenes/imagery
Physics-based thermal modeling
Mission preview
Intelligence preparation of the battlefield
Sensor simulation